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**ATTORNEY CONFIDENTIAL**  
**ENVIRONMENTAL ASSESSMENT  
OF THE  
CARTERET IMPOUNDMENTS  
AMERICAN CYANAMID COMPANY  
LINDEN, NEW JERSEY**

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**JUNE 3, 1988**

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## 1.0 INTRODUCTION

### 1.1 Purpose

The purpose of this report is to present a summary and compilation of the subsurface and hydrologic investigations of the Carteret Impoundments conducted to date and the results of an assessment of the human health and environmental risks presented by the impoundments.

Subsurface and hydrologic investigations compiled for this report include:

Waste characterization studies completed by HYDROSYSTEMS, Inc. in May, 1986,

Preliminary leachate and groundwater investigations completed by HYDROSYSTEMS in May, 1986,

Surface water quality investigations completed by HYDROSYSTEMS in October, 1986, and

Groundwater monitoring results for three quarterly groundwater sampling events using monitoring wells installed under the supervision of HYDROSYSTEMS in May through August, 1987.

The objectives of these investigations were to:

1. Characterize the nature of the waste and determine if it is a hazardous waste based on pH or the EP Toxicity Characteristic Test for metals under the Resource Conservation and Recovery Act (RCRA).
2. Identify potential constituents of concern in the waste and leachate.

3. Evaluate the extent of the release of potential constituents of concern from the impoundments.
4. Characterize the behavior and fate of the potential constituents of concern along the groundwater and surface-water migration pathways.
5. Identify the potential receptors of the constituents of concern that are released by the impoundments, and evaluate the human health and environmental risk presented by the releases.

## 1.2 Site History

Figure 1 shows the location of the Carteret impoundments on a portion of the Arthur Kill, New York-New Jersey topographic quadrangle map. The impoundments were used from 1906 to 1973 for the disposal of acidic sludge from an alum process and basic yellow prussiate of soda (YPS) sludge from the Prussian blue dye process. The sludges from the two processes were combined in the impoundments to form a neutral sludge. A series of six impoundments were constructed above ground with wooden and earthen dikes. The sludges were pumped from the plant on the north side of the Rahway River to the impoundments through an above-ground pipeline. The impoundments eventually covered approximately 126 acres and are estimated to contain just under two million tons of sludge.

## 2.0 SOLID WASTE CHARACTERIZATION

In May of 1986, HYDROSYSTEMS conducted investigations to ascertain whether the sludge should be classified a hazardous waste under the RCRA characteristics of pH or EP Toxicity for metals. Eight borings were completed in the sludge to allow

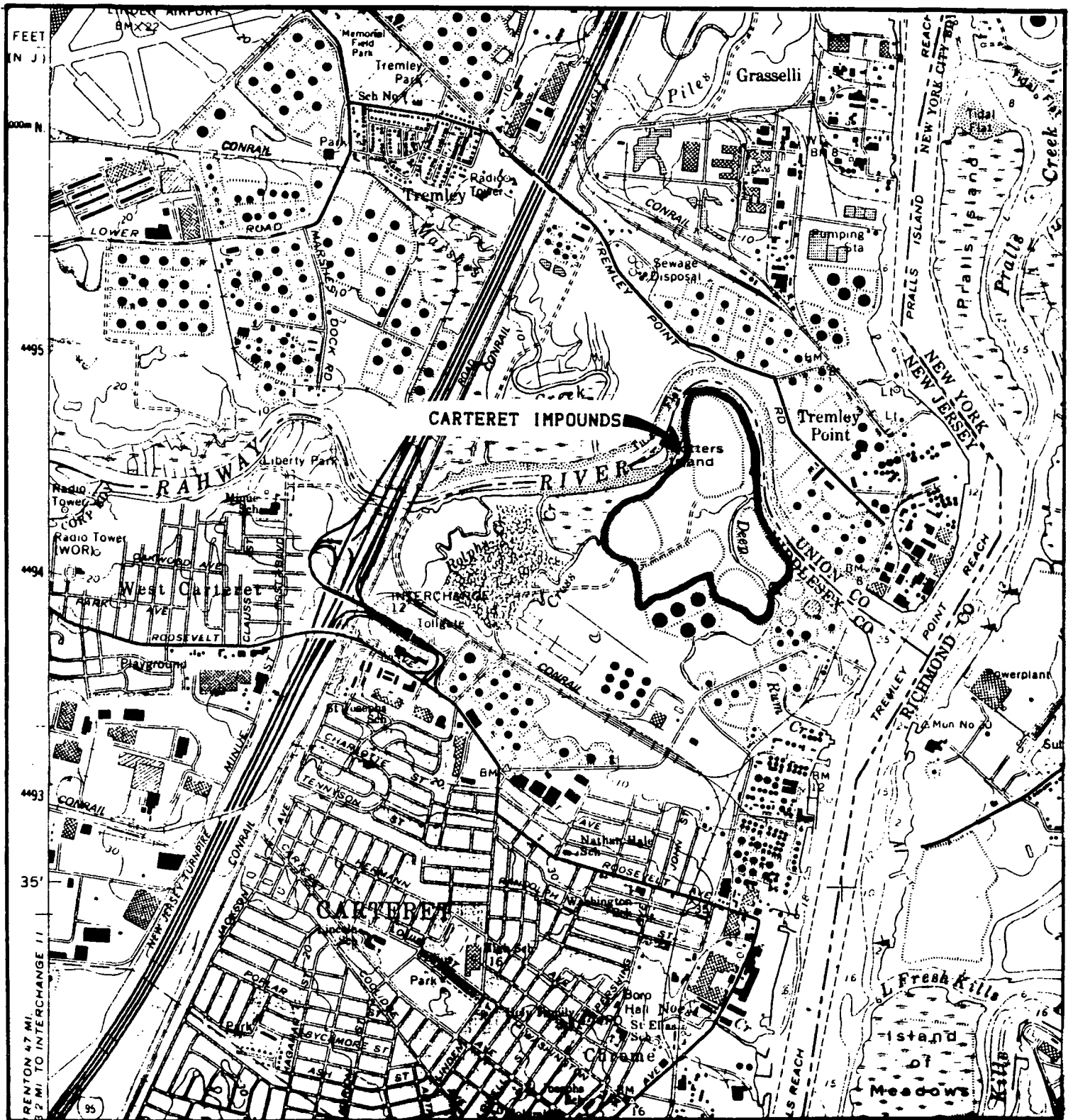


Figure 1. Location map for the Carteret impoundments, Carteret, New Jersey.

measurement of the pH of the sludge/leachate in the field and collect samples of sludge for laboratory analysis of EP Toxicity for metals.

Added  
Added  
Seven  
The field pH measurements of leachate in contact with sludge were made using "colorpHast" brand pH indicator strips, a product of EM Science (catalog no. 9590, pH range of 0-14). Results of the six field pH measurements are presented in Table 1. With an average pH of 7.3 and the six pH values being either 7 or 8, the leachate is nonhazardous with respect to the RCRA characteristic for pH. Since the pH of the leachate in contact with the sludge is in the neutral range, the sludge is assumed to have a pH in the neutral range, and, therefore, is not hazardous on the basis of pH.

Used  
Seven  
Seven samples of sludge were analyzed for EP Toxicity for metals and total and free cyanide content. Two of the seven sludge samples were duplicate samples from the same borings. Table 2 presents the results of the EP Toxicity and cyanide analyses for the sludge samples. Laboratory data for these analyses are included in Appendix A.

The results of the EP Toxicity tests indicate the sludge is nonhazardous with respect to metals. All metal concentrations in the EP Toxicity test leachate were below the RCRA criteria.

The results for the cyanide analyses of the sludge indicate a total cyanide concentration of from 433 to 3660 mg/kg with an average of 1133 mg/kg. The free cyanide, i.e., uncomplexed cyanide, concentration ranged from 9 to 103 mg/kg with an average of 36 mg/kg. The source of the cyanide in the sludge is the YPS, which has the chemical formula  $\text{Na}_4\text{Fe}(\text{CN})_6$ .

**TABLE 1. Field pH of leachate in contact with sludge in the Carteret impoundments.**

BORING NO.	FIELD pH OF LEACHATE IN CONTACT WITH SLUDGE
B1b	7
B2	7
B4	7
B5	7
B6	8
B7	8
AVERAGE	7.3

**TABLE 2. Laboratory analyses for EP Toxicity and Free and Total Cyanide content in sludge samples from the Carteret impoundments.**

PARAMETER	METHOD OF ANALYSIS (NOTE 1)	DETECTION LIMIT (MG/L)	EP TOXICITY CRITERIA (MG/L)	SAMPLE NO.- BORING NO.- IMPOUND NO.-	C1 B1a 4	C2 B2 5	C2* B2 5	C3 B3 6	C4 B4 3	C4* B4 3	C5 B5 2	BLANK
ARSENIC	ICP	0.2	5.0		BDL	BDL	NA	BDL	BDL	BDL	BDL	BDL
BARIUM	ICP	0.2	100.0		BDL	BDL	NA	BDL	BDL	BDL	BDL	BDL
CADMIUM	ICP	0.05	1.0		BDL	BDL	NA	BDL	BDL	BDL	BDL	BDL
CHROMIUM	ICP	0.05	5.0		BDL	BDL	NA	BDL	BDL	BDL	BDL	BDL
LEAD	ICP	0.2	5.0		BDL	BDL	NA	BDL	BDL	BDL	BDL	BDL
MERCURY	CV	0.0003	0.2		BDL	BDL	BDL	BC	BC	NA	BDL	BDL
SELENIUM	ICP	0.2	1.0		BDL	BDL	NA	BDL	BDL	BDL	BDL	BDL
SILVER	ICP	0.05	5.0		BDL	BDL	NA	BDL	BDL	BDL	BDL	BDL
UNITS FOR CYANIDE ANALYSES IN MG/KG												
												AVERAGE
TOTAL CYANIDE	335	0.5	NONE		683	452	NA	3660	437	NA	433	1133
FREE CYANIDE	412	0.5	NONE		14	18	NA	103	38	NA	9	36

**NOTES:**

- ICP = INDUCTIVELY COUPLED PLASMA SPECTROMETRY  
CV = COLD VAPOR ATOMIC ABSORPTION SPECTROSCOPY  
335 = METHOD 335.2 OF STANDARD METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTE, EPA-600/4-79-020, REVISED MARCH 1983.  
412 = METHOD 412 OF STANDARD METHODS, 16TH EDITION 1985.
- BDL = BELOW DETECTION LIMIT  
BC = BELOW EP TOXICITY CRITERIA  
NA = NOT ANALYZED  
\* = DUPLICATE

There are no RCRA EP Toxicity criteria for either total or free cyanide (40 CFR Part 261.24). However, soluble salts and complexes of cyanide are listed as hazardous constituents in Appendix VIII of the hazardous waste regulations under RCRA. In addition, the sludge may also be classified as a hazardous waste if it is considered a wastewater treatment sludge from the production of iron blue pigments (EPA hazardous waste no. K007 in 40 CFR Part 261.32). Under CERCLA, the National Contingency Plan (40 CFR Part 302) lists various cyanide salts as hazardous substances with reportable quantities of 10 pounds.

### 3.0 LEACHATE CHARACTERIZATION

At the same time the samples of sludge were collected for the EP Toxicity tests, samples of leachate in contact with the sludge were collected and analyzed for total and free cyanide. The results of these analyses are presented in Table 3. These results indicate that the sludge is releasing cyanide to infiltrating precipitation with maximum observed concentrations of total and free cyanide on the order of 124 and 2.4 mg/l, respectively. Laboratory data for these analyses are included in Appendix A.

The total cyanide in the shallow groundwater (depth to the water table was less than one foot) in borings 6 and 7 located about 20 feet outside of Impoundment 4 were 62 and 49 mg/l, respectively. The decrease in the observed concentration of total cyanide from as high as 124 mg/l inside the impoundments to 62 mg/l just outside indicates significant dilution and/or attenuation of the cyanide in the shallow groundwater.

The measurement of the pH of leachate in contact with the sludge, as reported in section 2.0, indicated an average pH of 7.3.

**TABLE 3. Laboratory analyses for total and free cyanide in leachate in contact with sludge in the Carteret Impoundments.**

PARAMETER	METHOD OF ANALYSIS (NOTE 1)	DETECTION LIMIT (MG/L)	SAMPLE NO.- BORING NO.- IMPOUND NO.-	CART-2 B2 5	CART-4 B4 3	CART-5 B5 2	CART-6 B6 (NOTE 2)	CART-7 B7 (NOTE 2)	BLANK
(UNITS IN MG/L)									
TOTAL CYANIDE	335	0.5		85.00	124.00	105.00	62.00	49.00	0.013
FREE CYANIDE	412	0.5		0.33	2.40	0.50	2.30	0.55	0.007

NOTES:

(UNITS IN MG/L)

- 335 = METHOD 335.2 OF STANDARD METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTE, EPA-600/4-79-020, REVISED MARCH 1983.  
  
412 = METHOD 412 OF STANDARD METHODS, 16TH EDITION 1985.
- SAMPLES CART-6 AND CART-7 REPRESENT SHALLOW GROUNDWATER SAMPLES FROM DEPTHS OF ABOUT ONE FOOT TAKEN FROM BORINGS B6 AND B7 WHICH WERE ABOUT 20 FEET OUTSIDE OF IMPOUNDMENT 4.

## 4.0 GROUNDWATER CHARACTERIZATION

### 4.1 Field Investigations

In order to conduct a complete assessment of the groundwater conditions at the site, five monitoring well clusters were installed. All wells were positioned outside of the impoundments; no well clusters were placed in the waste materials. The locations of the wells, which are numbered MW-1 through MW-5, are indicated in Figure 2. Each cluster consists of two wells: a shallow well, designated "S", screened in the black organic sand and/or red-brown clay overlying the Brunswick Shale; and a deep well, designated "D", screened in the Triassic-aged Brunswick Formation. The screened interval in MW-5S also includes a portion of construction debris fill material encountered in the upper portion of that borehole. The deep well at location MW-5 was not screened in the Brunswick because a permeable sand and gravel zone was encountered overlying the shale. The screen was placed in the sand and gravel in order to allow for sampling of groundwater from this zone.

The wells were drilled with a mud-rotary rig using bentonite drilling fluid. An 8-inch rock drill bit was used and all wells were installed with 4-inch ID, Schedule 40, flush-jointed, threaded PVC well casing and 10 foot lengths of 0.020-inch machine slotted PVC well screens. Sand pack consisting of coarse-grained #2 quartz sand was placed around each well screen to a minimum of 1 foot above the top of the screen. Approximately 2 feet of bentonite pellets were placed above the sand pack to form the seal. The wells were then grouted to about 2 feet below ground surface with a 5% bentonite/cement slurry. Steel casings with locking caps were installed and cement was brought to the

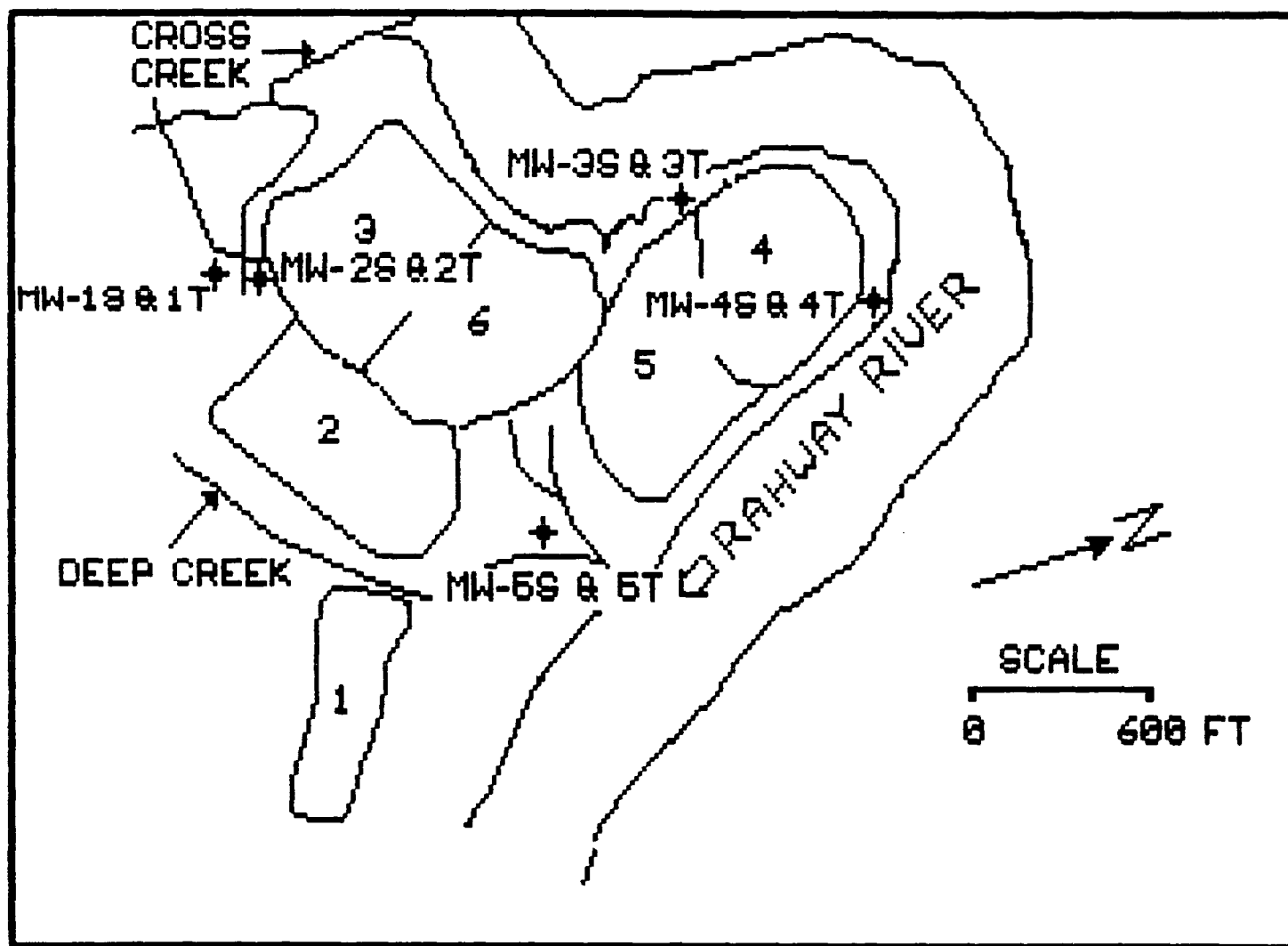


Figure 2. Locations of Monitoring Well Clusters at the Carteret Impoundments.

surface. Monitoring well construction diagrams and geologic logs are included in Appendix B. Also, the State of New Jersey permit to drill the wells and the monitoring well certification, Form A, for each well are included in Appendix B.

The wells were developed after installation by pumping with a 4-inch submersible pump until the discharged water remained clear of silt and drilling fluid. Approximately one week after the initial development, the wells were developed again using a suction lift centrifugal pump and bailer.

#### 4.2 Hydrostratigraphy

The inactive alum impoundments at Carteret are located on the boundry between the Piedmont and Coastal Plain physiographic provinces. Surficial deposits consist of about 20 to 40 feet of Quaternary alluvium composed of interbedded silt, sand, gravel, and clay with buried peat and organic rich horizons. The alluvium was deposited in a salt-marsh environment. (1,2)

Bedrock underlying the alluvium is the Triassic-age Brunswick Formation consisting of bedded shales, mudstones and sandstones which attain a maximum thickness of 6,000 to 8,000 feet in New Jersey. (1)

The approximate locations of the test borings completed by M. Disko Associates in 1981 (2) are shown in Figure 3. The geologic logs for borings reported by Disko (2) and shown along the lines labeled A-B and B-C in Figure 3 were used to construct the geologic cross-sections shown in Figures 4 and 5. Although not all the borings were completed to bedrock, their interpretation indicated that the top of bedrock is 20 to 30 feet below land surface and 15 to 20 feet below the base of the impoundments. The alluvial sediment consists of 4 to 6 feet of meadow mat and 7

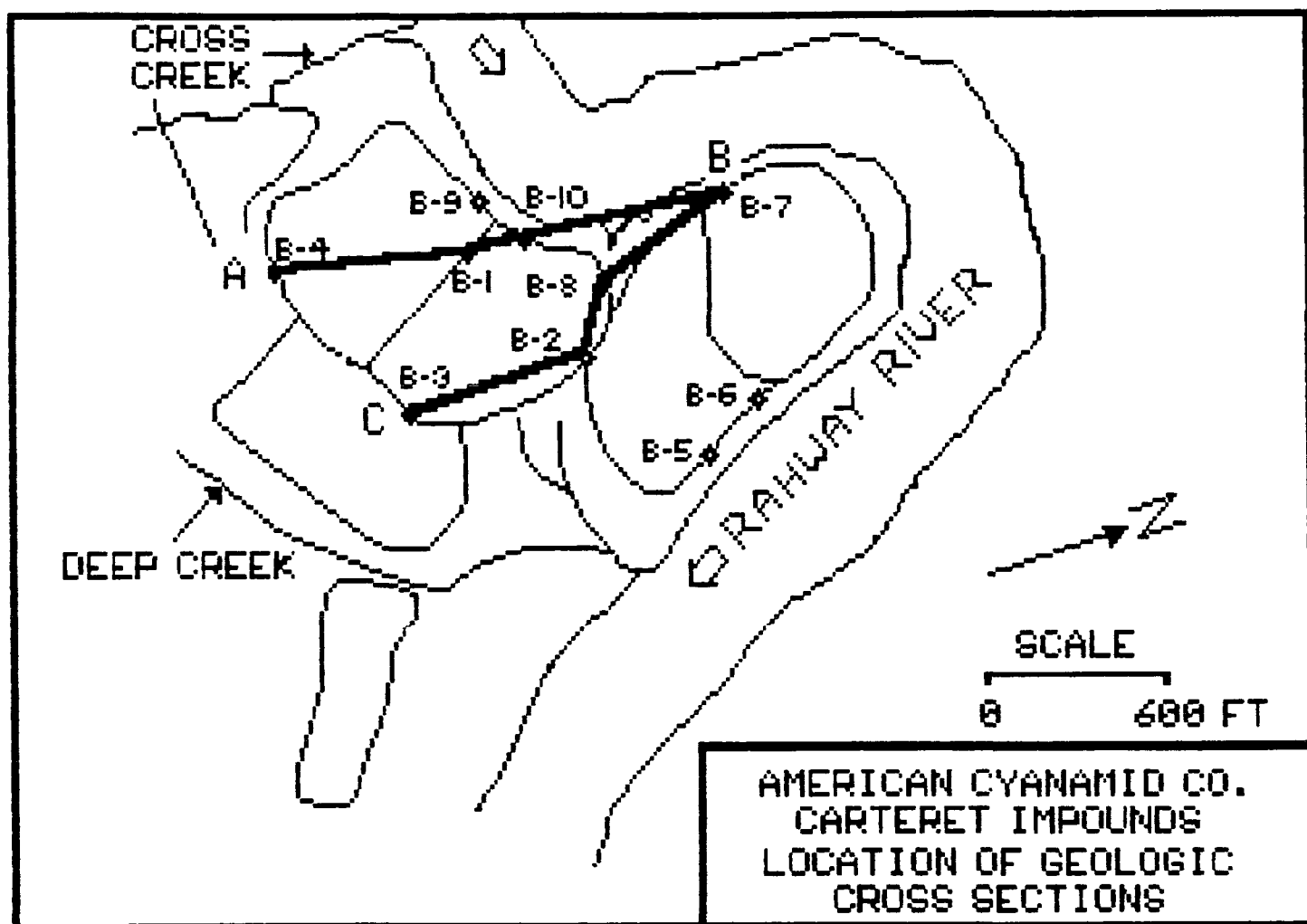


Figure 3. Site map showing the locations of the borings installed by M. Disko Associates at the Carteret Impounds. Cross-sections A-B and B-C are indicated on the map.

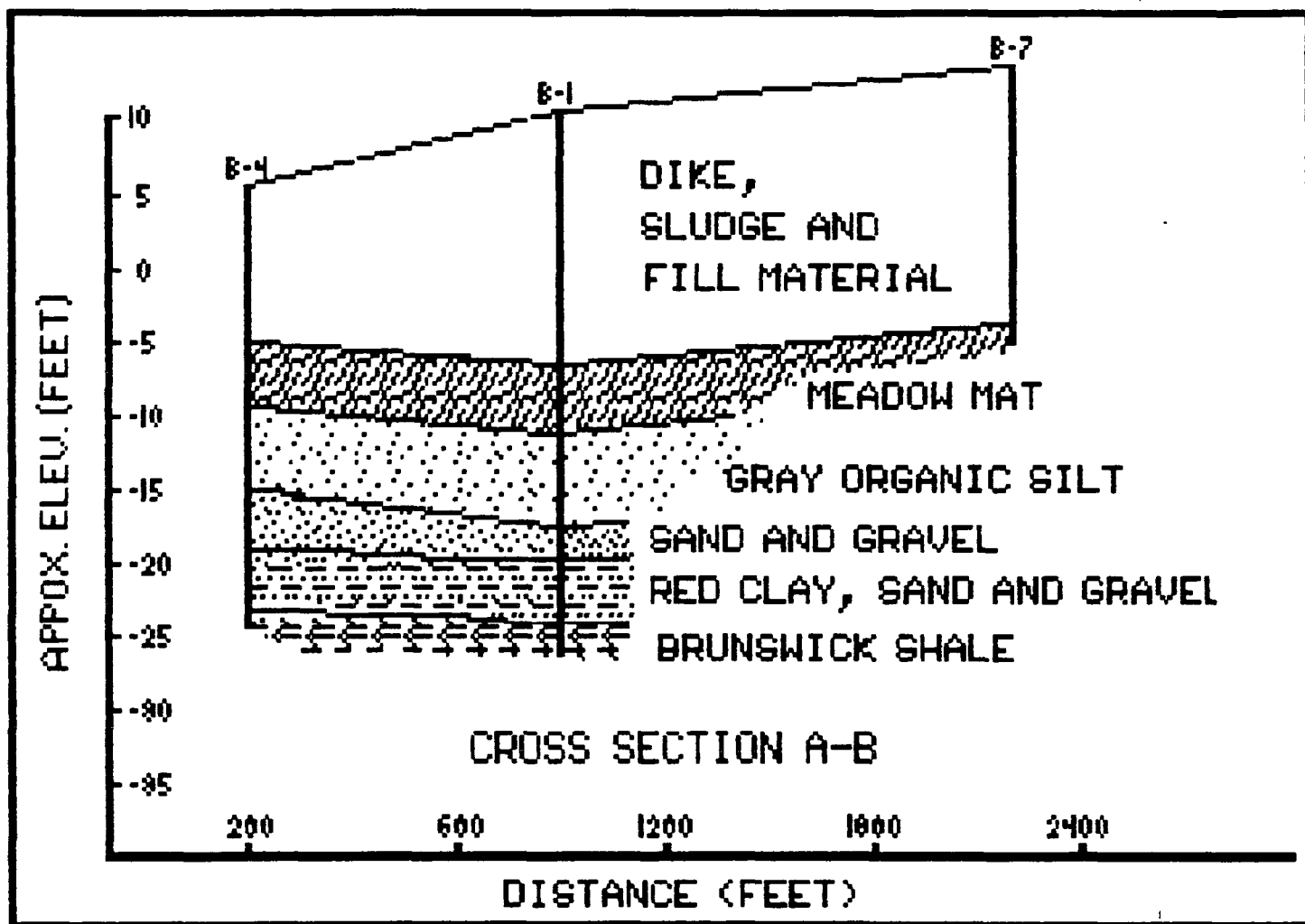


Figure 4. Geologic cross-section along line A-B shown in Figure 3 for the Carteret Impoundments.

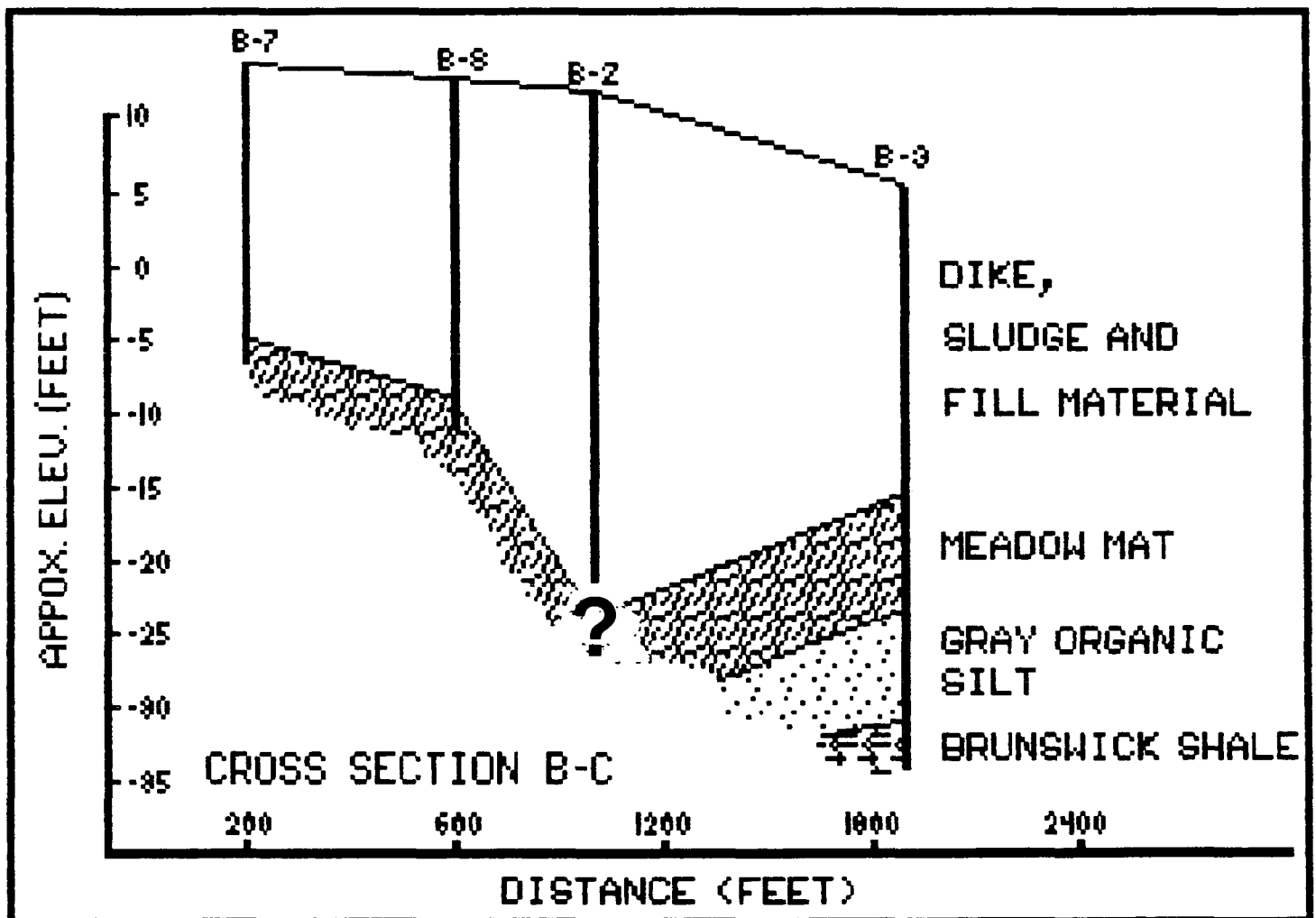


Figure 5. Geologic cross-section along line B-C shown in Figure 3 for the Carteret Impoundments.

to 9 feet of silt with minor amounts of sand, gravel, and clay.  
(2) Based on the interpretation of Disko's boring logs and the manner of impoundment construction, the meadow mat appears to underlie the entire area of the impoundments.

During monitoring well installation around the impoundments, split-spoon samples were collected in the unconsolidated sediments and fill material. Geologic logs were constructed for each well cluster (included in Appendix B). The logs for MW-1, MW-2, MW-3 and MW-4 indicate the presence of 10 to 25 feet of a black organic sand, corresponding to the meadow mat, gray organic silt, and sand and gravel zones encountered in the Disko borings. The shallow wells at these four locations were screened in this material. A continuous zone of red-brown clay, approximately 8 to 25 feet thick, exists beneath the organic sand in these wells and corresponds to the red clay layer present in Disko borings B-1 and B-4 (See Figure 4).

A dense, hard, red and grey siltstone, typical of the Brunswick Formation, was encountered beneath the clay at a depth of from 30 to 42 feet below ground surface in these four wells. The deep wells at these four locations were screened in the Brunswick Formation. At location MW-5, the black organic-rich sand layer encountered in the borings for MW-1 through MW-4 was not present and the shallow monitoring well was completed in the clay zone beneath the fill. The clay zone is most likely the same material encountered in the borings for MW-1 through MW-4. Beneath the clay, a zone of red-brown and grey sand and gravel was encountered in the boring for MW-5D. The screen for MW-5D was placed in this zone and the well was not drilled to the Brunswick Formation which was encountered at 32 feet.

The black organic-rich sand beneath the fill material (except for MW-5) constitutes the water table aquifer. The water table was encountered at a depth of approximately 2 feet below ground surface in most wells. The clay layer acts as a confining zone beneath the water table and restricts the vertical flow of groundwater. The Brunswick Formation forms the bedrock aquifer in the area and contains and transmits groundwater through fractures in the siltstone.

Two cross-sections have been constructed across the site using the information from the HYDROSYSTEMS borings and wells. The locations of the cross-sections are shown on Figure 6. Figure 7 shows cross-section D-E and indicates that the Brunswick aquifer is overlain by the clay confining layer. The water table aquifer occurs in the black organic-rich sand that overlies the clay. Note that the clay confining layer is continuous across the site in this section. Figure 8 shows cross-section F-G constructed through the wells and borings and indicates that the clay confining layer thins-out in the south-central side of the site since it was not encountered in boring B-3. The water table aquifer and the bedrock aquifer are therefore likely to be in hydraulic communication. The sand and gravel zone encountered beneath the clay in MW-5D is probably a localized deposit and is also hydraulically connected to the Brunswick aquifer.

#### **4.3 Aquifer Properties and Groundwater Flow Rates**

Disko (2) completed permeability tests on subsurface samples. He reported permeabilities ranging from  $2 \times 10^{-6}$  to  $3.8 \times 10^{-3}$  cm/sec (0.006 to 10 ft/d) for the clay, sand, and gravel materials he encountered in the upper 24 feet underlying the impoundments.

Effective porosity for the shallow aquifer material will range from about 20% for sands and gravels to 5% for clays and clayey silts.

The maximum hydraulic gradient for the shallow aquifer is on the order of 10 feet over 1,000 feet, or 0.01.

Based on the equation:

$$v = Ki/n$$

where  $v$  is groundwater pore velocity,  $K$  is the hydraulic conductivity,  $i$  is the gradient, and  $n$  is the effective porosity, the velocity may range from 0.001 ft/d for the clayey materials to 0.5 ft/d for the sands and gravels.

#### 4.4 Groundwater Flow

Water levels were measured in the 10 monitoring wells prior to evacuation and sampling for each quarterly monitoring event. The measured depth to water and casing elevations are provided in Appendix B. The water level elevations were calculated, and generalized groundwater contour maps were constructed for both

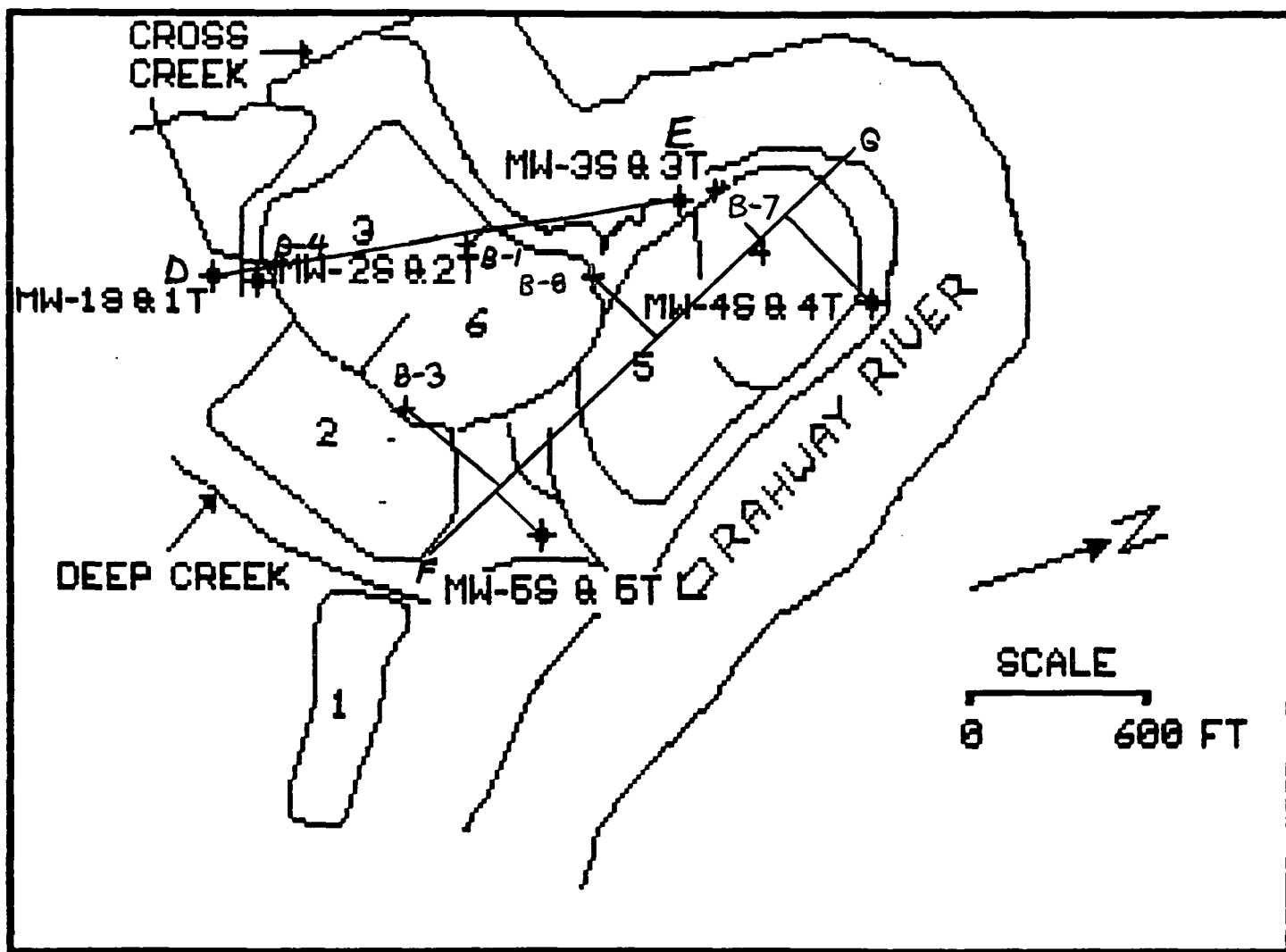


Figure 6. Site map showing the locations of cross-sections constructed using stratigraphic data obtained from the monitoring wells installed by HYDROSYSTEMS and borings installed by M. Disko Associates at the Carteret Impoundments.

# GEOLOGIC CROSS SECTION OF CARTERET IMPOUNDS

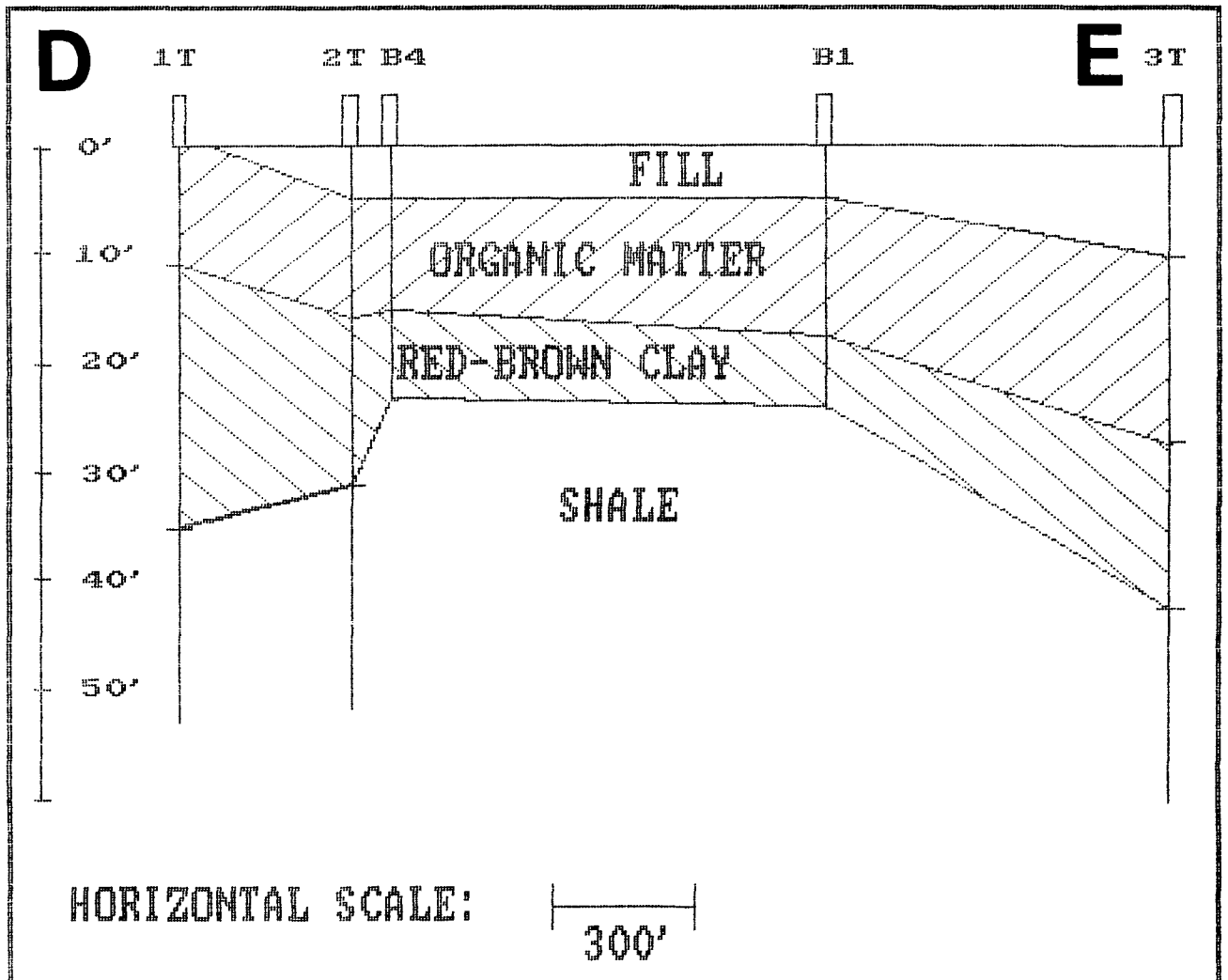


Figure 7. Geologic cross-section D-E for the Carteret impoundments (not corrected for elevation).

# GEOLOGIC CROSS SECTION OF CARTERET IMPOUNDS

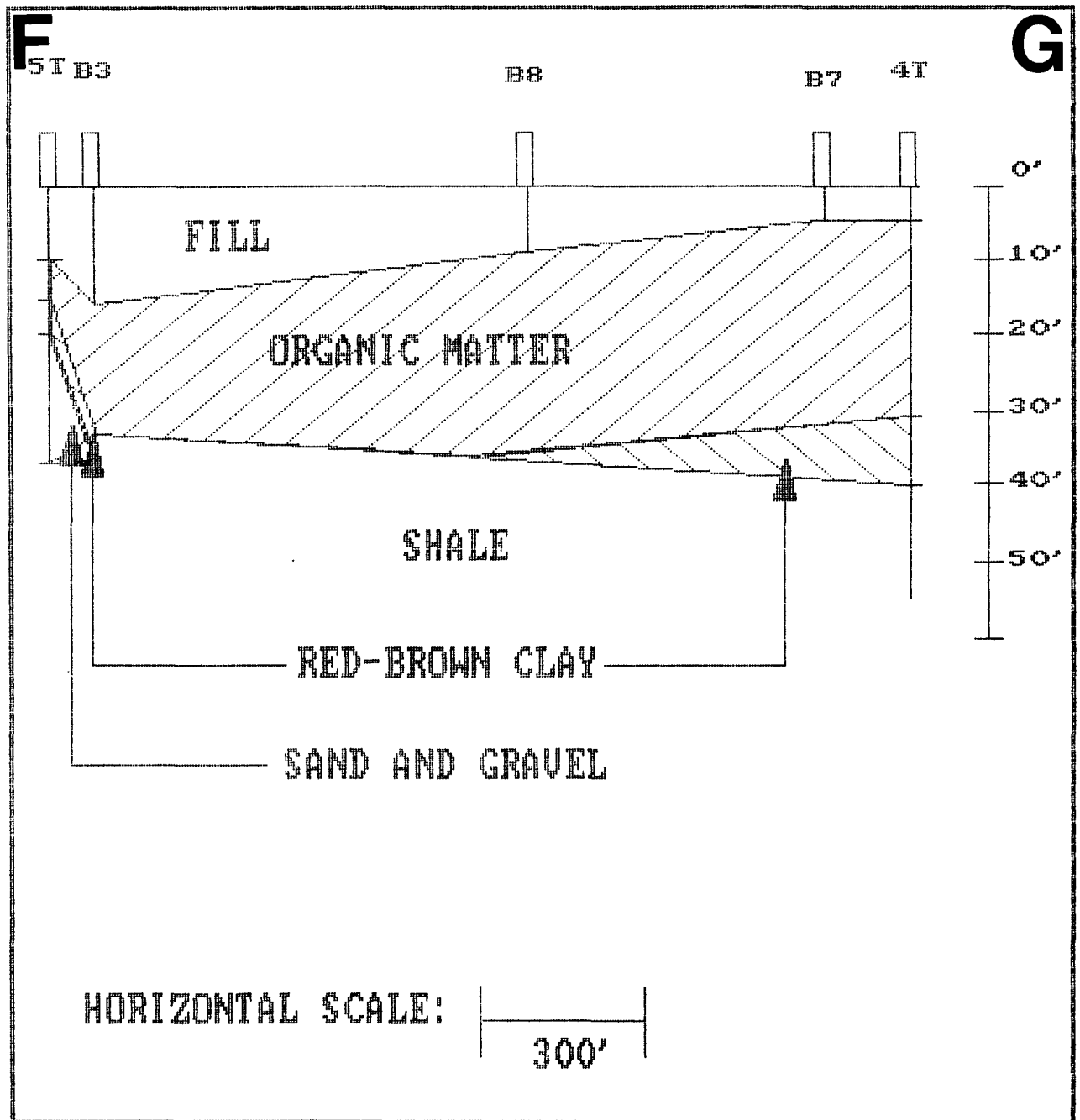


Figure 8. Geologic cross-section F-G for the Carteret impoundments (not corrected for elevation).

the shallow and deep zones and are presented in Figures 9 and 10. Estimated water table elevations collected while installing the hand-augered borings were also used to prepare the contour map of the shallow zone.

The contour map presented in Figure 9 indicates that shallow groundwater is mounded beneath the impoundments, and that groundwater flow is generally radially outward from the impoundments toward the Rahway River, Deep Creek, and Cross Creek. The impoundments act as a recharge zone for the shallow aquifer as a result of the relatively high infiltration capacity of the waste. Impoundments 4, 5, and 6 are topographically the highest and, as a result, the elevation of the water table is approximately 10 feet above mean sea level beneath these impoundments. The generalized contour map of groundwater elevations prepared for the deep zone also indicates a radial flow pattern similar to the shallow zone (See Figure 10). This is a result of downward flow from the upper aquifer beneath the impoundments converging with upward flow from the Brunswick aquifer. Flow is directed radially toward the Rahway River and surrounding tributaries.

The data collected to date are not sufficient to make a determination concerning the magnitude or direction of vertical flow beneath the site. The precise times of data collection were not recorded and, therefore, the tidal influence on the water level measurements is not known. If measurements were taken during a time of tidal fluctuation, and if levels were not measured within a very short time span, variations due to tidal movements may be significant between the shallow and deep wells in a cluster. Variations observed in vertical flow directions

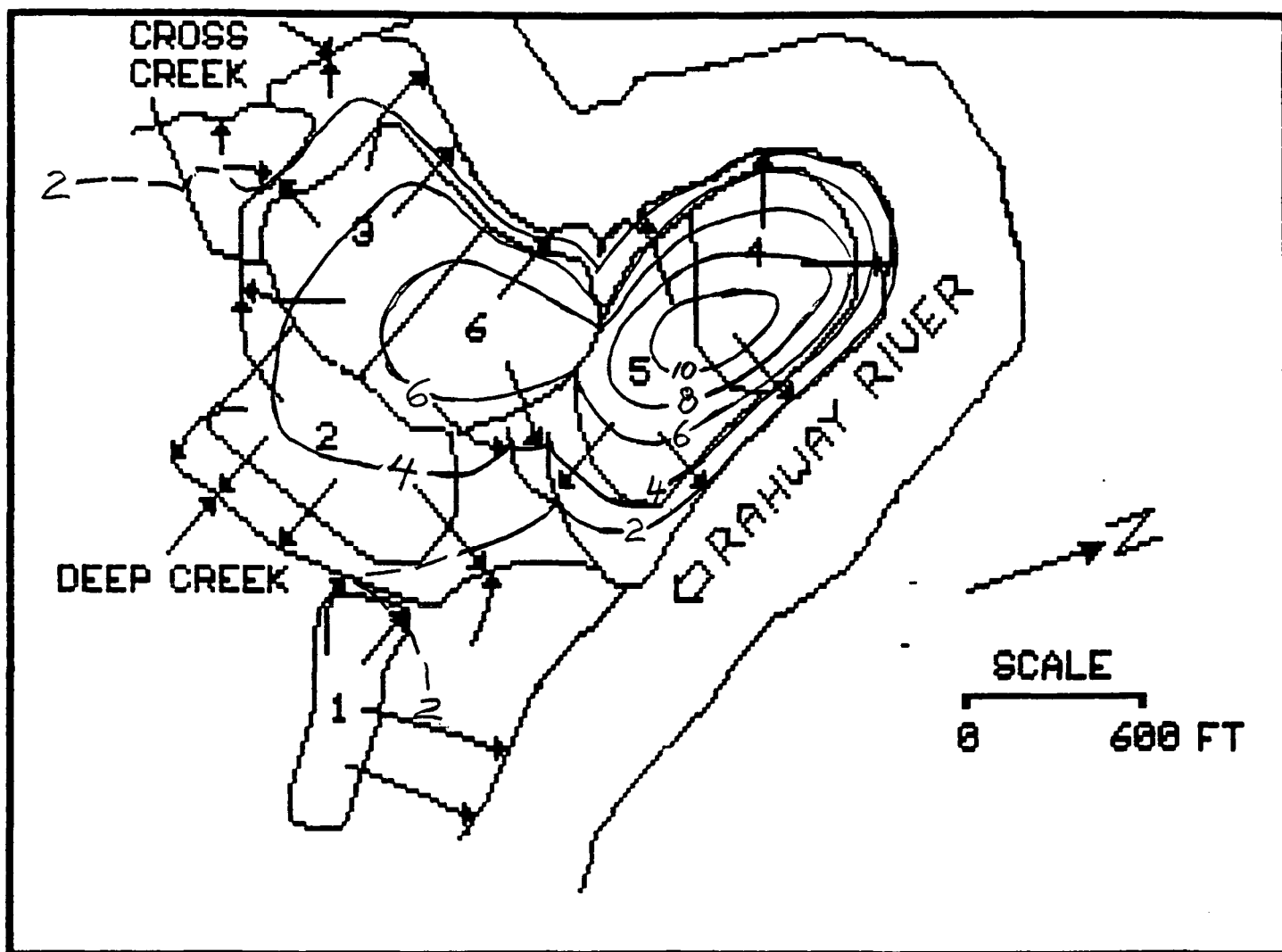


Figure 9. Generalized water table elevation contour map for the shallow aquifer showing groundwater flow directions (arrows).

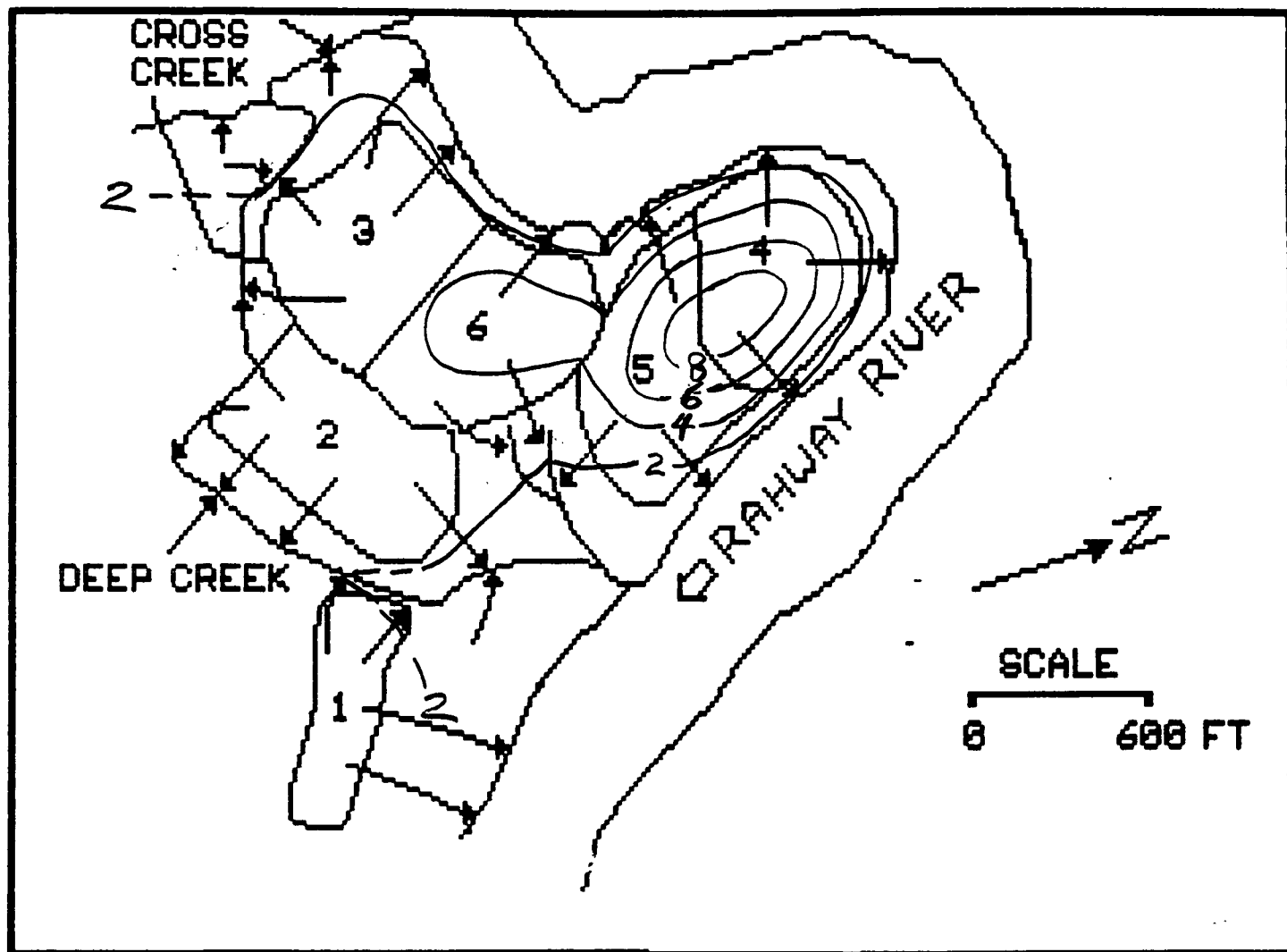


Figure 10. Generalized water table elevation contour map for the deep aquifer showing groundwater flow directions (arrows).

from the three sampling events may be the result of tidal influences.

Based on the observed radial groundwater flow patterns observed in both the shallow and deep horizons, a conceptual model of groundwater flow at the site has been developed. Figure 11 shows a generalized cross-section for the area. The model indicates that regional groundwater flow in the Brunswick Formation is seaward, toward the east, and that discharge to surface water takes place. The groundwater originating within the impoundments moves radially outward and also discharges into the surface water. This interpretation results in the hydraulic isolation of groundwater flowing from the impoundments. The mounded groundwater in the impoundments causes a downward flow component through the bottom of the impoundments. However, the upward regional flow of groundwater in the Brunswick aquifer should prevent significant downward migration of groundwater from the impoundments into the Brunswick.

In addition to upward flow in the Brunswick Formation, isolation of groundwater from the impoundments is further enhanced by a groundwater density differential. The mounded groundwater within the impoundments, i.e., leachate, is less dense than the underlying groundwater in the shallow and deep zones based on specific conductivities of about 1,000 umhos/cm for the leachate as compared to 17,000 to 38,000 umhos/cm for the shallow and deep groundwater. Therefore, the less dense groundwater within the impoundments would tend to "float" on top of the underlying brackish groundwater.

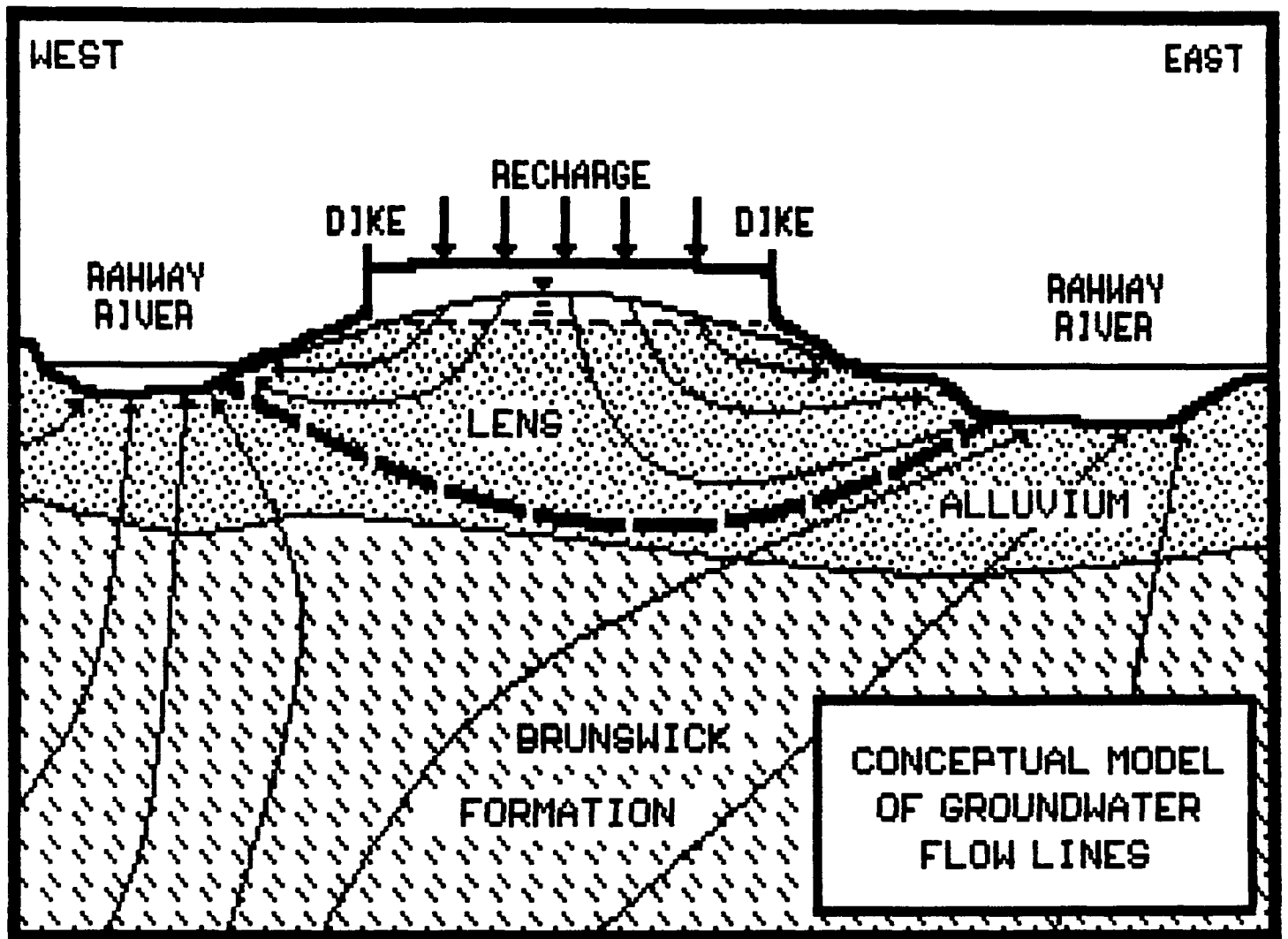


Figure 11. Generalized east-west cross-section beneath the Carteret impoundments showing the conceptualized groundwater flow system with a shallow flow system created by the mounded water table within the impoundments separated from a deeper groundwater flow system.

#### 4.5 Groundwater Quality

Three sets of groundwater samples have been collected from the 10 monitoring wells on July 31 and October 20, 1987 and January 19, 1988. Inorganic parameters including metals are analyzed quarterly. Cyanide and priority pollutant organics, including volatiles, acid extractables, base-neutrals, and pesticides/PCBs, are analyzed annually in January (except for the first sampling event of July, 1987). The analytical data from the laboratory are included in Appendix C.

Inorganic chemical data for each monitoring well have been summarized in Tables 4 through 8. Total cyanide, the primary contaminant of concern at the site, was analyzed for the July 31, 1987 and January 19, 1988 sampling rounds. Significant concentrations of total cyanide were detected in MW-2S, MW-4S and MW-5S at average values of 29 mg/l, 103 mg/l and 5.08 mg/l, respectively. MW-5D was the only deep monitoring well that showed cyanide contamination with concentrations ranging from 2.56 mg/l to 10.6 mg/l.

*See Table 4*  
Sodium concentrations were consistently higher in the shallow wells of each cluster indicating that the leachate from the sludge has higher sodium concentration than the groundwater in the Brunswick Formation. High values of total organic carbon (TOC) were found in MW-1S and MW-4S during all sampling events. The average TOC concentrations were 439 mg/l and 139 mg/l for MW-1S and MW-4S, respectively. However, chloride and total dissolved solids (TDS) concentrations do not indicate any characteristic trends between the shallow and deep aquifers.

**TABLE 4. Summary of analyses for major inorganic constituents in groundwater samples for wells 1S and 1D.**

PARAMETER	DETECTION LIMIT	WELL 1S				WELL 1D			
		7/31/87	10/20/87	1/19/88	AVERAGE	7/31/87	10/20/87	1/19/88	AVERAGE
CHLORIDE	1.0	5830	5780	6530	6047	9800	9260	9400	9487
SODIUM	0.110	2930	4180	3190	3433	2140	2450	2300	2297
SULFATE	5.0	310	760	990	687	800	790	800	797
TOTAL CYANIDE	0.025	0.348	NA	0.057	0.203	BDL	NA	BDL	BDL
CHROMIUM, +6	0.01	BDL	NA	BDL	0.007	BDL	NA	BDL	BDL
MANGANESE	0.0048	3.5	NA	10.9	7.2	6.810	NA	6.76	6.74
TDS	10.0	11900	16600	13900	14133	26600	24900	19700	23733
TOC	1.0	329	762.5	226	439	22.2	4.3	5.7	10.7
TOX	0.005	1.36	1.6	3.48	2.15	2.42	1.57	6.75	3.58

NOTE - CONCENTRATIONS IN MG/L.

NA = PARAMETER NOT ANALYZED

BDL = BELOW DETECTION LIMIT

**TABLE 5. Summary of analyses for major inorganic constituents in groundwater samples for wells 2S and 2D.**

PARAMETER	DETECTION LIMIT	WELL 2S				WELL 2D			
		7/31/87	10/20/87	1/19/88	AVERAGE	7/31/87	10/20/87	1/19/88	AVERAGE
CHLORIDE	1.0	9460	9770	8110	9113	10100	11000	10900	10667
SODIUM	0.110	5370	5840	4690	5300	4900	5450	5280	5210
SULFATE	5.0	2890	3780	12500	6390	1000	940	880	940
TOTAL CYANIDE	0.025	17.1	NA	41	29	1.16	NA	BDL	0.59
CHROMIUM, +6	0.01	BDL	NA	BDL	BDL	BDL	NA	BDL	BDL
MANGANESE	0.0048	0.60	NA	0.02	0.31	1.42	NA	1.04	1.23
TDS	10.0	20700	22900	18100	20567	21900	22900	19420	21407
TOC	1.0	29.1	17.4	25	23.8	12.6	5.5	6	8.0
TOX	0.005	1.77	2.27	7.1	3.71	1.46	0.69	4.96	2.37

NOTE - CONCENTRATIONS IN MG/L.

NA = PARAMETER NOT ANALYZED

BDL = BELOW DETECTION LIMIT

**TABLE 6. Summary of analyses for major inorganic constituents in groundwater samples for wells 3S and 3D.**

PARAMETER	DETECTION LIMIT	WELL 3S				WELL 3D			
		7/31/87	10/20/87	1/19/88	AVERAGE	7/31/87	10/20/87	1/19/88	AVERAGE
CHLORIDE	1.0	11800	12000	12500	12100	7750	11100	11300	10050
SODIUM	0.110	NA	6120	6120	4080	3550	5130	5200	4627
SULFATE	5.0	110	290	44	148	NA	1090	1090	1090
TOTAL CYANIDE	0.025	ND	NA	BDL	BDL	0.280	NA	BDL	0.153
CHROMIUM, +6	0.01	BDL	NA	BDL	BDL	BDL	NA	BDL	BDL
MANGANESE	0.0048	0.42	NA	0.05	0.235	0.802	NA	0.765	0.784
TDS	10.0	20900	22200	20400	21167	NA	24800	20900	22850
TOC	1.0	69	41.7	37.5	49.4	NA	7.9	11.8	9.9
TOX	0.005	2.51	0.125	2.31	1.65	NA	0.465	1.68	1.07

NOTE - CONCENTRATIONS IN MG/L.

NA = PARAMETER NOT ANALYZED

BDL = BELOW DETECTION LIMIT

**TABLE 7. Summary of analyses for major inorganic constituents in groundwater samples for wells 4S and 4D.**

PARAMETER	DETECTION LIMIT	WELL 4S				WELL 4D			
		7/31/87	10/20/87	1/19/88	AVERAGE	7/31/87	10/20/87	1/19/88	AVERAGE
CHLORIDE	1.0	16300	16100	17100	16500	11600	11600	11300	11500
SODIUM	0.110	8200	8710	9140	8683	4140	4290	4410	4280
SULFATE	5.0	3120	3290	3240	3217	1186	1160	1090	1145
TOTAL CYANIDE	0.025	106	NA	100	103	0.700	NA	0.535	0.618
CHROMIUM, +6	0.01	BDL	NA	BDL	BDL	BDL	NA	BDL	BDL
MANGANESE	0.0048	BDL	NA	BDL	BDL	1.47	NA	1.41	1.44
TDS	10.0	28100	29800	27900	28600	25100	26300	22000	24467
TOC	1.0	NA	179	120	150	21.4	12.2	8.8	14.1
TOX	0.005	1.4	0.3	2.91	1.54	1.56	0.53	2.33	1.47

NOTE - CONCENTRATIONS IN MG/L.

NA = PARAMETER NOT ANALYZED

BDL = BELOW DETECTION LIMIT.

**TABLE 8. Summary of analyses for major inorganic constituents in groundwater samples for wells 5S and 5D.**

PARAMETER	DETECTION LIMIT	WELL 5S				WELL 5D			
		7/31/87	10/20/87	1/19/88	AVERAGE	7/31/87	10/20/87	1/19/88	AVERAGE
CHLORIDE	1.0	9790	14500	14900	13063	12100	12000	9120	11073
SODIUM	0.110	6400	7130	7130	6887	5460	5690	5000	5383
SULFATE	5.0	130	350	250	243	470	670	1410	850
TOTAL CYANIDE	0.025	4.05	NA	6.1	5.08	2.56	NA	10.6	6.58
CHROMIUM, +6	0.01	BDL	NA	BDL	BDL	BDL	NA	BDL	BDL
MANGANESE	0.0048	0.330	NA	0.033	0.182	1.550	NA	0.606	1.078
TDS	10.0	25000	26300	23900	25067	21000	23500	17400	20633
TOC	1.0	39.4	32	30.7	34.0	26	13.4	24	21.1
TOX	0.005	1.22	3.22	2.17	2.20	1.11	0.89	1.86	1.29

NOTE - CONCENTRATIONS IN MG/L.

NA = PARAMETER NOT ANALYZED

BDL = BELOW DETECTION LIMIT

Analytical results for VOCs indicate the presence of several compounds, detected during both sampling events, in samples collected from MW-1S. Table 9 summarizes the compounds detected and the concentrations. Benzene, ethylbenzene, and toluene, in addition to several chlorinated organics are present in these groundwater samples. Concentrations of some of the VOCs, specifically 1,1-dichloroethane, methylene chloride, and toluene increased in the second sampling event. This possibly indicates that the source of contamination is still present at the site and continues to affect groundwater quality. Additionally, ethylbenzene and toluene were detected in MW-5D during the January 19, 1988 sampling at concentrations of 70.4 ug/l and 21.4 ug/l, respectively. Likewise, since these compounds were previously undetected in this well, a trend of increasing contamination exists. Very low concentrations of methylene chloride detected in several samples are considered to be the result of laboratory contamination.

Several phenolic compounds and some base - neutral extractable compounds were also detected in MW-1S during the July 31, 1987 sampling event. Specifically, phenol, at a concentration of 66.8 ug/l, isophorone at 168 ug/l and nitrobenzene at 28.8 ug/l were present. Phenol was also detected in wells MW-3S and MW-4S at concentrations of 4.92 ug/l and 22.5 ug/l, respectively.

**TABLE 9. Summary of analyses for organic constituents in groundwater samples for well 1S.**

PARAMETER	DETECTION LIMIT	WELL-1S		TRIP BLANK
		7/31/87	1/19/88	7/31/87
BENZENE	4.4	195	207	BDL
CHLOROBENZENE	6.0	18.2	34	BDL
1,1-DICHLOROETHANE	4.7	65.5	127	BDL
1,1-DICHLOROETHYLENE	2.8	19	23.7	BDL
ETHYLBENZENE	7.2	21.9	29.9	BDL
METHYLENE CHLORIDE	2.8	BDL	150	15.5
TOLUENE	6.0	2940	4340	BDL
1,1,1-TRICHLOROETHANE	3.8	18.4	67.3	BDL
TRICHLOROETHYLENE	1.9	83.5	98.3	BDL
VINYL CHLORIDE	10.0	12.3	19.9	BDL
CHLOROETHANE	10.0	45.1	36	BDL
1,2-TRANS-DICHLOROETHYLENE	1.6	72.6	86.7	BDL

NOTE - ALL CONCENTRATIONS IN UG/L.  
BDL = BELOW DETECTION LIMIT

#### 4.6 Potential Groundwater Receptors

The Brunswick aquifer is a major source of groundwater to the west of the site with wells producing from depths of about 150 feet. Even in areas where the Brunswick is used as a source of water, the groundwater has been reported to be locally high in sulfate and hardness due to the presence of evaporite deposits, i.e., gypsum and salt (2). In the vicinity of the Carteret impoundments, the high salinity of the groundwater would preclude the use of the Brunswick aquifer as a source of groundwater.

Based on the information gathered concerning the groundwater flow system at the site, HYDROSYSTEMS feels that no water supply wells producing from the Brunswick aquifer will draw groundwater that originates in the impoundments. The survey of groundwater usage conducted by M. Disko Associates in 1982 (2) indicates that no water supply wells are located downgradient of the impoundments. The closest water supply well to the impoundments is 4,000 feet southwest and upgradient of the site near the intersection of Roosevelt Avenue and the New Jersey Turnpike. This well, reportedly owned by Gulf Stream Development, has a reported yield of 100 gpm which is too low to cause a reversal in groundwater flow at the distance of the impoundments.

## 5.0 SURFACE WATER PATHWAY

### 5.1 Surface Water System

The Carteret impoundments are in the Rahway River drainage basin, located between 0.5 and one mile upstream of the confluence with the Arthur Kill. The impoundments are bordered on the north and east by the Rahway, on the west by a small tributary to the Rahway named Cross Creek, and on the south and east by another small tributary to the Rahway called Deep Creek (shown in Figure 1). These surface waters are tidal with average tidal variations on the order of four feet.

### 5.2 Surface Water Flow

The flow of the Rahway River has been monitored by the U.S. Geological Survey at Rahway, New Jersey. For the water years 1922-1984, the average flow of the Rahway was 47.5 cubic feet per second (1).

### 5.3 Surface Water Quality

During May 15-16, 1986, one grab sample of the Rahway River was collected along the south bank of the river next to the impoundments. Analysis of that grab sample indicated a total cyanide concentration of 2.0 mg/l and a free cyanide concentration of 0.084 mg/l. A second grab sample was collected in Cross Creek near the front gate for the road leading into the impoundments. Analysis of the Cross Creek sample indicated a total cyanide concentration of 0.37 mg/l and a free cyanide concentration of 0.012 mg/l.

Based on these preliminary analyses of surface water, Joel Jerome (Environmental Project Manager with American Cyanamid Company)

applied a surface water transport model to the Rahway River to evaluate the potential impacts of cyanide releases. The model used was the Quirk, Lawlar, Metuski one-dimensional, steady-state, conservative transport model that was developed for the Arthur Kill, Newark Bay, Raritan River, and Raritan Bay systems. Based on the outcome of the model, using inputs of 0.084 mg/l free cyanide and a leachate discharge of 17,000 cubic feet per day, no adverse impact on the Rahway River was predicted.

To confirm the absence of an impact on the Rahway River, a comprehensive surface water study was conducted in October 1986. Figure 12 shows the locations of the surface water sampling points in the Rahway River upstream and downstream of the impoundments, in Cross Creek, and in Marsh Creek opposite the impoundments. The upstream and downstream stations in the Rahway River consisted of three stations at each location providing samples one-quarter, one-half, and three-quarters across the channel. At each station, the sample was collected from a four-foot interval centered on the mid-depth. In water less than four feet deep, the sample represented the full column of water. Each station was sampled twice, at high (except stations 7 and 8 in the creeks) and low tides. Appendix D presents the laboratory reports for the surface water analyses for total and free cyanide.

The results of the river sampling program indicate that both total and free cyanide were below the detection limit of 0.025 mg/l in all samples for the Rahway River and Marsh Creek opposite the impoundments. The sample collected in the mouth of Cross Creek was reported to have 0.032 mg/l of total cyanide and 0.032 mg/l of free cyanide.

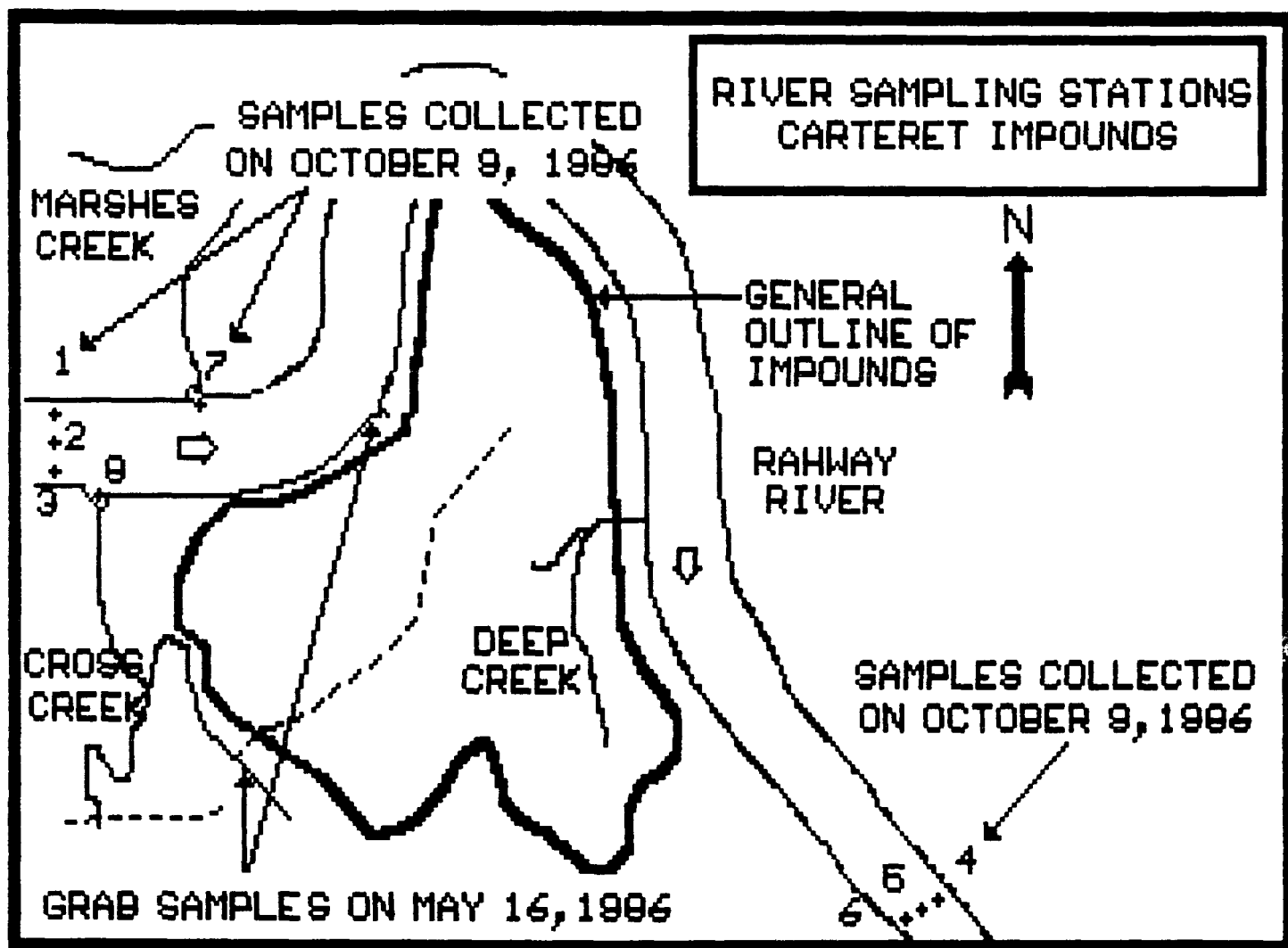


Figure 12. Locations of surface water sampling stations for the October 1986 study.

#### **5.4 Potential Surface Water Receptors**

No surface water intakes for drinking water are known downstream of the impoundments. The Rahway River and its tributaries in the vicinity of the impoundments are brackish with observed salinities of 15 parts per thousand. In comparison, sea water salinity is approximately 33 parts per thousand off the coast of New Jersey (6).

## 6.0 FATE OF CYANIDE IN SURFACE WATER AND GROUNDWATER

The fate of cyanide that is released in leachate leaving the Carteret impoundments is dominated by three processes: dilution, volatilization, and biodegradation. These processes operate to reduce the concentration of both total and free cyanides in water as it migrates from the impoundments. Figure 13 presents a conceptual diagram of the fate of cyanide in water at the site.

The dilution of the leachate by the flow in the Rahway River is estimated to average 235 times, based on the 47.5 cfs ( $4 \times 10^6$  cfd) average river flow and the 17,000 cfd estimated average leachate production rate.

Callahan et al. (5) report that in water with a pH less than 8, over 90% of the free cyanide will be in the form HCN (hydrogen cyanide), which is highly volatile (5). Therefore, the free cyanide will volatilize from surface water and groundwater, and decrease the concentration of total cyanide as the equilibrium between complexed and free cyanide shifts towards the free cyanide (see arrow pointing from M:CN to HCN (aqueous) in Figure 13).

Biodegradation of cyanide occurs in all organisms where the cyanide concentration is below toxic levels (5). This fate process probably is more important in surface water than in the groundwater due to the generally higher biological activity and lower cyanide concentrations.

The EPA (9) reports a half-life of between 0.33 and 0.80 days in surface water, which would be representative of the combined effects of volatilization and biodegradation.

CONCEPTUAL MODEL FOR  
FATE OF CYANIDE IN HYDROSPHERE

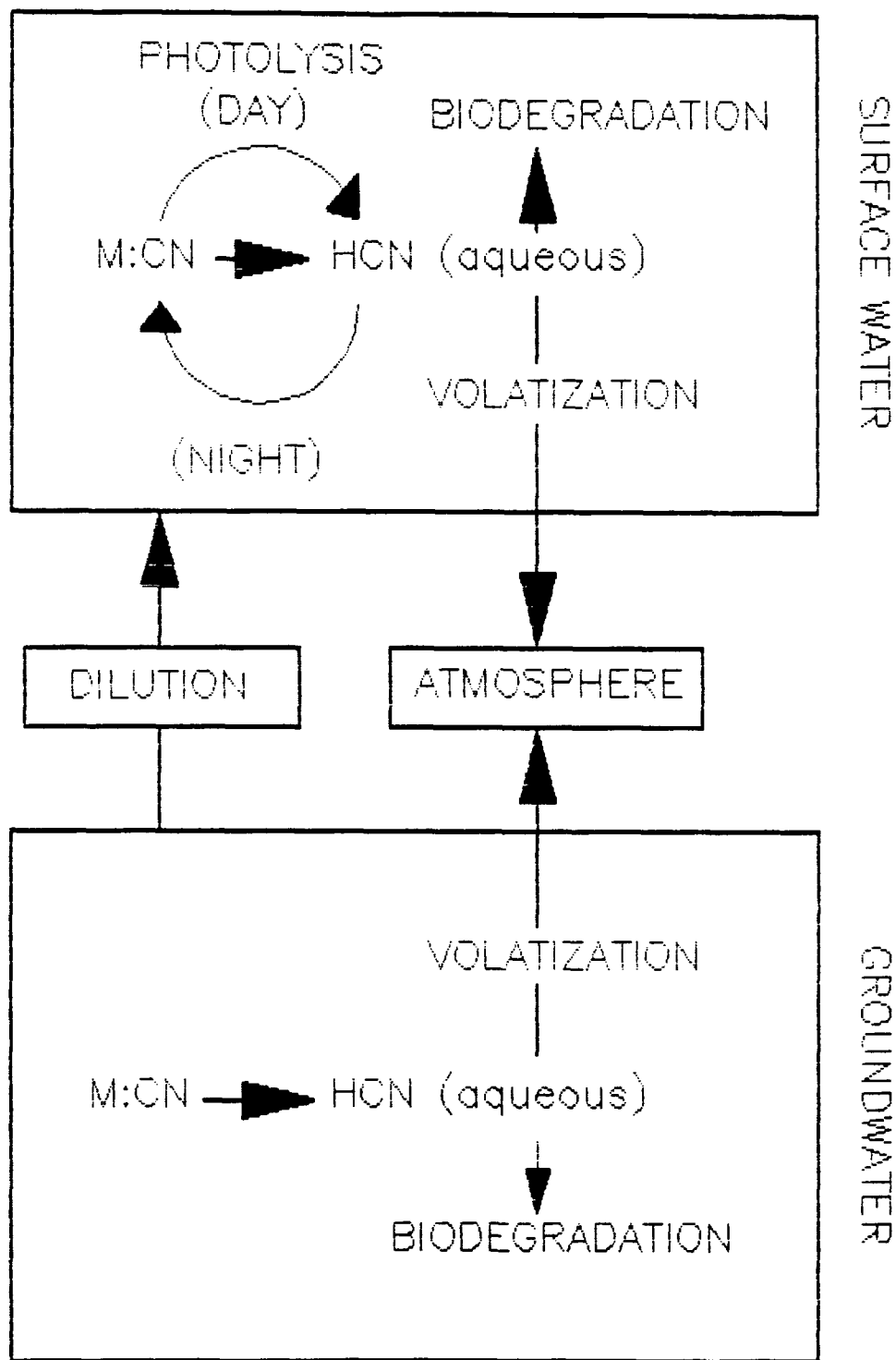


Figure 13. Conceptual model of the fate of cyanide in water at the Carteret impoundments.

In the case of the Carteret impoundments, with total cyanide concentrations in the leachate averaging 85 mg/l, a total reduction factor of 3,400 times is required to decrease the cyanide to below the 0.025 mg/l detection limit for the Rahway River samples. Thus, with an average dilution rate due to mixing of leachate with the Rahway River of about 235, the other processes of volatilization and biodegradation must account for an additional factor of approximately 10 to 15 times.

## **7.0 HUMAN HEALTH AND ENVIRONMENTAL ASSESSMENT**

### **7.1 Human Health Assessment**

Based on the results of the sludge, leachate, groundwater, and surface water analyses, the only constituent of concern being released from the impoundments is cyanide. Since no surface water or groundwater sources of drinking water are downgradient or capable of drawing water that originates in the impoundments, there are no potential risks to human health via drinking water.

Since the impoundments are inaccessible to unauthorized persons, risks to human health via direct contact are virtually nil.

Risk to human health via ingestion of fish caught in the Rahway River is also nil since cyanide is not bioaccumulated (5).

### **7.2 Environmental Assessment**

The U.S. Environmental Protection Agency (EPA) reports that the effects of cyanide on marine life have not been adequately investigated to determine a water quality criteria for marine life. The EPA states that the alkaline nature of marine waters reduces the toxicity of cyanide to fish.

The State of New Jersey water quality criteria for the Rahway River and its tributaries in the vicinity of the impoundments does not list cyanide. The state criteria are applied to surface waters on the basis of salinity. The salinity of the Rahway River (ranging from 15 to 21.5 parts per thousand on October 9, 1986), places these surface waters in the "SE" classification for saline estuaries (Title 7, Chapter 9, section 7:9-4.4). The criteria for SE classified waters does not contain cyanide (ibid., section 7:9-4.14c).

However, the standards promulgated under the New Jersey Pollutant Discharge Elimination System (NJPDDES) establishes a water-quality criteria of 0.03 mg/l free cyanide for protection of aquatic life in salt water (Title 7, Chapter 14, section 7:14a, Appendix F, Values for Determination of NJPDDES Permit Toxic Effluent Limits). The results of the surface water analyses discussed in section 5.3 indicate that the Rahway River adjacent and downstream of the impoundments achieves the NJPDDES standard of 0.03 mg/l free cyanide (all samples were below 0.025 mg/l free and total cyanide). Although the grab sample collected along the bank was reported to have a free cyanide level of 0.084 mg/l, the mixing zone for the leachate entering the river is limited based on the absence of detectable cyanide in any of the downstream river stations.

## 8.0 REPORTABLE QUANTITY ASSESSMENT

A release of 10 pounds of cyanide in any 24 hour period constitutes a reportable release under the National Contingency Plan requirements. With an estimated average volume of leachate of 17,000 cfd and an average total cyanide concentration in leachate of 85 mg/l, the estimated amount of cyanide being released to the environment is:

$$85 \text{ mg/l} * 1 \text{ lb}/454000 \text{ mg} * 17,000 \text{ cfd} * 7.48 \text{ gal/cf} * 4.23 \text{ l/gal} = 100 \text{ lbs/d}$$